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A Fram Strait Experiment: Sensing Sea Ice Conditions using Shipborne GNSS Reflectometry

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Cruises of the Norwegian research vessel (R/V) Lance provide regular in-situ measurements of ocean and sea ice properties in Fram Strait, at the major link between the Arctic and the Atlantic Ocean. A GNSS reflectometry (GNSS-R) setup has been installed aboard R/V Lance to investigate sea ice remote sensing opportunities during the Fram Strait 2016 cruise. The experiment is based on previous coastal investigations, which demonstrated the ocean altimetric potential of GNSS-R and its sensitivity to the sea ice cover. The presence of sea ice can be detected by the reduced sea surface roughness that affects the coherence of the GNSS-R carrier phase. Differential phase observations of the reflected signal relative to the direct signal are considered here.

The objective of this study is the retrieval of the coherent differential phase resolving the altimetric effect of changes in the sea ice thickness. Grazing reflections with satellite elevations < 30° are of special interest as they potentially increase the observation coverage on the sea surface. In case of airborne or spaceborne setups, at more than 1km altitude above sea level, the atmospheric refraction of GNSS signals introduces significant biases in the differential phase especially at grazing elevations. The shipborne setup with antenna heights of 24 m above sea level allows to study grazing reflections disregarding the atmospheric bias.

The setup slightly differs from common shipborne GNSS equipment. It consists of a GORS (GNSS Occultation Reflectometry Scatterometry) receiver, based on commercial JAVAD hardware. Two antenna links are starbord-looking with right- and left-handed circular polarization to detect the reflected signal. One right-handed antenna is up-looking for reference to the direct signal.

In-phase and quadrature (I,Q) samples from the three antenna links were recorded during the entire Fram Strait cruise, between 25 August and 13 September 2016. The ship's track on its main section went from Svalbard at 10° E roughly along 79° N to the Eastern Greenland coast at 13° W and back. Different ice conditions were encountered: open water with a rough sea surface close to Svalbard, a dense coverage of multiyear drift ice in the centre of Fram Strait and multiyear fast ice at the Greenland coast.

The recorded events comprise about 920 hours of observations with an almost omnidirectional view and 1° to 30° elevation. Most data can be referred to sea surface reflections. However, parts are also affected by multipath from the ship. The specular reflection power ratio is mapped over the entire cruise and the signal direction. Low ratios (< 30 dB) are characteristic for the rough open sea period. High ratios (up to 80 dB) occur during the drift and fast ice periods and indicate the improved phase coherence for ice observations.

In this ongoing study further effects will be investigated heading for the altimetric estimation of ice thickness. It includes the GNSS signal penetration into the ice, the effect of permanent changes of the ship attitude and requirements of further GNSS receiver modifications.